Tab E

Preliminary Research and Development Roadmap for Protecting and Assuring the Vital Human Services Infrastructure*

* This document is one component of a longer report entitled *Preliminary Research and Development Roadmap for Protecting and Assuring Critical National Infrastructures* (Transition Office of the President's Commission on Critical Infrastructure Protection and the Critical Infrastructure Assurance Office. Washington, D.C. July 1998). For more information, please see <URL:http://www.ciao.gov/>.

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Section 1
Introduction

1.1 Scope of the Infrastructure

The President's Commission on Critical Infrastructure Protection has examined the eight critical infrastructures identified in Executive Order 13010. While this work was underway, it became convenient to group some of the original critical infrastructures into a single category. This new category, called vital human services, encompasses three infrastructures: water-supply systems, emergency services, and government services.

Water-supply systems are characterized by sources of water; reservoirs and holding facilities; aqueducts and other transport systems; filtration, cleaning, and treatment systems; pipelines; cooling systems; and other delivery mechanisms that provide water for domestic and industrial applications. Also included in this infrastructure are systems for dealing with water runoff, wastewater, and fire-fighting needs.

Emergency services encompass medical, police, fire, and rescue systems, and their personnel who respond to emergencies. These services typically are provided at the local level (city, county, or metropolitan area). In addition, however, state and federal response plans define emergency support functions to assist in mitigation plans and in preparation, response, and recovery activities from various incidents.

Government services refer to the ability of federal, state, and local governments to provide essential services to the public during and after an emergency. Types of emergencies include natural disasters (e.g., floods and hurricanes), military attacks, technological emergencies, or other emergencies that seriously degrade or threaten our nation's security. Preparedness planning in this area requires identifying functions that are required during an emergency, identifying personnel to perform those functions, and developing plans and the capability to execute those plans. This critical infrastructure is closely linked with each of the other infrastructures considered by the Commission.

1.2 Characterization of the Infrastructure

The vital human services infrastructure provides services used by a large number of our nation's citizens and residents. Water-supply systems typically provide water to metropolitan areas as well as to many rural areas for uses such as irrigation. Providing wastewater treatment is also a common function of government organizations. These services are provided on an "on-demand" basis and are essential for maintaining public health.

The emergency services category includes both planning for, and responding to (during and after), emergencies. As such, any member of the general public is a potential recipient of these services. Emergency services must also be provided on an “on-demand” basis to avoid endangering the health and safety of people or their property.

Depending on the services provided, the public relies on government services with varying levels of urgency, reliability, and quantity. Maintaining or restoring government services during and after an emergency is the main research and development (R&D) objective for this part of the vital human services infrastructure.

1.3 Issues and Trends

The three components within vital human services are significantly intra- and interdependent. For example, government services may not be able to provide adequate fire-fighting services if the water-supply system is not operating. Likewise, emergency response functions can be hampered if part of the transportation infrastructure is out of order. Therefore, the vital human services critical infrastructure is inexorably linked to the other infrastructures and requires interagency coordination and cooperation.

The vital human services infrastructure typically is funded through one or more types of tax. In this era of tax cuts and shrinking government, these services frequently do not receive sufficient financial support to maintain current standards of service. This lack of support is especially relevant to new areas of emphasis that traditionally have not received significant support from available resources. Protection of the infrastructure has not been emphasized in the past; however, it is now becoming an area of great concern.

Section 2
Threats and Vulnerabilities

Because the three components of the vital human services infrastructure are intradependent as well as interdependent, they share many of the same threats and vulnerabilities. However, some threats and vulnerabilities relate primarily to one component. Each of the components of the vital human services infrastructure is discussed in detail below.

2.1 Water-supply Systems

The water supplied to U.S. communities is potentially vulnerable to terrorist attacks by insertion of biological agents, chemical agents, or toxins. The possibility of such an attack is of considerable concern, as current news headlines have highlighted. Individuals who harbor political differences with the present government are capable of conducting such attacks. Moreover, international problems, such as the current situation with Iraq, lend credibility to the notion that independent or foreign government-sponsored terrorists could initiate an attack of this kind.

Most U.S. water-supply systems are fairly safe from attacks initiated when contaminants are introduced upstream (e.g., reservoirs, lakes, rivers) because hazardous agents either do not mix well (chemical agents and toxins) or survive (biological agents) in water. Most urban water systems supply a high volume of water that effectively dilutes the toxic properties of contaminating agents and thereby provides a protective element. Unfortunately, rural water systems and distribution networks may not have this same protective element. Although highly lethal biological agents, such as anthrax and botulinum toxin, would not generally pose a threat of contamination to water-supply systems, these agents could be a threat if they were inserted at critical points in the system; theoretically, they could cause a large number of casualties. Furthermore, a recent outbreak of cryptosporidosis in Milwaukee is a good illustration of how large populations can be infected when water treatment is compromised. In this instance, the illness was associated with a fairly unique microbe, *Cryptosporidium parvum*, which is immune to normal water treatment and survives well in water.

In addition to being vulnerable to biological and chemical contamination, water-supply systems are also vulnerable to physical and cyber attacks. For example, pumping stations can be quite vulnerable to attacks that would require many months to recover. Some municipal water-supply systems are also vulnerable to attacks on industrial facilities. An attack can lead to a release of pollutants into their water outflow systems, which could, in turn, contaminate nearby intake systems for the municipal systems. Furthermore, many water-supply systems are operated by means of computer systems, which are vulnerable to cyber attacks. R&D topics in these areas are discussed later.

In general, vulnerability or risk evaluations that involve biological or chemical attacks by terrorists have not been performed for U.S. water-supply systems. However, a limited number of systems have been evaluated on behalf of the Commission. The results of these analyses indicated that most water-supply systems are vulnerable to a terrorist attack through the distribution network. Moreover, additional vulnerabilities can also be present.

Although, in general, vulnerability analyses of possible terrorist attacks have not been conducted, every system examined on behalf of the Commission had provisions in place for responding to natural disasters and system failures. These provisions ranged from system monitoring to emergency response plans. Although the industry has considered natural disasters and system failures, additional research in fault-tree analysis of low-probability events would be beneficial. Also, R&D activities are needed to assess system vulnerability and the risk from terrorist attack. R&D directed toward reducing the effects of terrorist attacks would also be appropriate.

Training methods must be developed and implemented so that water-system employees can detect, evaluate, and respond to biological and chemical incidents. Methods of communicating and working with professional emergency response personnel regarding such incidents must be integrated into this training program.

2.2 Emergency Services

The general, potential threats to water-supply systems are also of great concern to emergency services personnel. Among the most vulnerable persons in emergency services are the first responders, typically local police, fire, and/or emergency medical personnel. The attack in Tokyo, for example, in which a chemical agent was introduced into a subway tunnel highlights the vulnerability of first responders. Fortunately in that case, terrorists used an agent that was short-lived and inefficiently distributed; otherwise, casualties would have been much higher.

In most U.S. communities, the first responders to accidents, explosions, or incidents that involve human illness are fire fighters, police officers, and emergency medical technicians (EMTs). They are specially trained to deal with a variety of materials, but not with weapons of mass destruction, such as biological or chemical warfare agents. The U.S. Department of Defense (DoD) recognizes this deficiency and has initiated a series of seminars, exercises, and tests to train and inform management and response teams about the hazards of these agents and to identify and demonstrate improved response procedures and equipment.

Despite the training and heightened awareness of biological and chemical toxicities, first responders do not have adequate detection and personal protection equipment. This equipment needs to be portable, rugged, sensitive, and quantitative; it also must be capable of providing rapid results. For example, the Chief of the Chicago

Fire Department envisions a portable unit that is part of a fire-fighter’s oxygen backpack and that reports readings on a heads-up display in the faceplate of the fire-fighter’s mask.

2.3 Government Services

In effect, government services are subject to most of the threats and vulnerabilities faced by the other critical infrastructures. This conclusion is based on the complexity of the government services area and its interdependencies on the services provided by the other infrastructures. Within vital human services, government typically is responsible for providing water-related services and emergency response, so the relationship to threats and vulnerabilities is even stronger. Of course, government services has its own set of threats and vulnerabilities as well, in that government personnel and facilities are potential targets. Terrorists may see them as a means to make political statements and expose perceived weaknesses in local, state, or federal government.

Section 3
R&D Topics and Activities

The vital human services R&D team identified several areas in which R&D is needed. These topics were selected on the basis of the personal knowledge of the team members, discussions with other experts, and the findings of earlier work done on behalf of the Commission.

The following subsections summarize information about R&D in these areas. These topics are categorized on the basis of their respective components of the vital human services infrastructure to ease characterization of the R&D topics. The descriptions and discussions of threats and vulnerabilities show the significant intra- and interdependency among these topics. They can affect more than a single component of the vital human services infrastructure and also more than one critical infrastructure.

A general challenge in establishing an R&D program for this critical infrastructure is to integrate it with ongoing programs within DoD; the U.S. Department of Energy; other federal, state, and local agencies; and organizations in the private sector. The needs for vital human services must be factored into the goals of other research programs to minimize duplication of effort among the programs and to ensure that optimum use is made of the limited resources available.

3.1 Water-supply Systems

Potential topics and activities for R&D in water-supply systems include identifying and developing countermeasures for potential biological and chemical contaminants; developing detection equipment to identify potential contaminants of concern within a water-supply system; evaluating system vulnerability and risk to both biological and chemical agents and to physical and natural phenomena; developing information systems to promote a response that effectively minimizes adverse impacts; and developing system-specific contingency plans.

3.1.1 Identification and Characterization of Biological and Chemical Agents

Description

Many types of biological and chemical agents can be used to disable a drinking water-supply system. Of these agents, a number require basic research to determine how they would “behave” in a water-supply system. A database or registry of such biological and chemical agents would be a valuable asset. This database or registry could include the physical and chemical properties of the agents and characterize their behavior in an environment containing disinfectant agents, such as chloramine or hypochlorite. For example, it is not known how the nerve agent VX or botulinum toxin would behave in a disinfectant environment typical of post-treatment, water-distribution networks. Similarly, the solubility of trichotecene mycotoxin T-2, another chemical agent of concern, has not been measured in the laboratory. Tests of these agents could be made under actual conditions experienced in water-supply systems. For example, chlorine and chloramine levels, the pH level, and other parameters may vary within and among water-supply systems, and it is important that suspected agents and their countermeasures be tested under the appropriate conditions.

A second component of this R&D topic is additional applied research to investigate the actual risks of certain threat agents or materials. Often, insufficient data are available to give an accurate prediction of the ability of these materials to adversely affect human health or to identify appropriate treatment or antidotes if people have been exposed to them.

Some research is already being conducted in this area, and any new work would be designed to complement existing programs. Among the programs already underway are those at Aberdeen Proving Ground and those conducted on behalf of the Chemical and Biological Defense Command within DoD.

Goals and Challenges

One goal for this research is to develop solid data concerning water solubility and stability for all agents of concern. In addition, researchers need to gather information that shows the effectiveness of various countermeasures, including treating the water system, supplying antidotes, and providing other forms of medical assistance to affected parties. This information could be compiled in an electronic format and made available to the vital human services community for their use.

A major challenge in this area is the large number of potential biological and chemical agents for which information needs to be developed, compiled, and made available.

Rationale for the Research and Desired Results

Because the number of biological and chemical agents potentially available to terrorists continues to increase, basic information is needed on (1) the behavior of these agents in water-supply systems and (2) the risks they pose to the public. The research described here provides a scientific foundation upon which to base decisions regarding the threats posed by these agents.

The results of this research would lead to the development of an information database on biological and chemical agents. In addition, such a database would have potential for use in evaluating terrorist activities directed at water-supply systems.

Timeframe and Resource Requirements

This effort would be a continuing process, as researchers characterize more agents as potential terrorist weapons. In the near-term (before 2002),[1] researchers would characterize the spectrum of agents that are known or that lack sufficient data. They also would identify some agents not currently suspected. To meet near-term goals would require approximately two to three years of effort. The cost is estimated to be about $14 million. Subsequent efforts over the mid-term timeframe (2003–2005) would involve identifying currently unknown agents and characterizing their physical and chemical parameters and behavior. Researchers would identify risks and develop countermeasures, as well as develop and implement a database and information exchange mechanisms. Estimated expenditures for this research are likely to increase because of the unknown, but potentially large, number of agents. A total cost of $15 million is estimated to be required for these efforts.

New agents for use by terrorists and new risks for water-supply systems are likely to be identified for many years to come. Therefore, it is proposed that the research in identification and characterization be continued for at least five years, that is to 2010. This additional R&D would occur approximately from 2006 to 2010 and cost an estimated $25 million.

3.1.2 Biological and Chemical Agent Detectors

Description

A major deficiency in protecting our water-supply system infrastructure needs to be addressed. That deficiency is detecting contaminants. To eliminate this problem, researchers need to develop detectors that can identify potential biological and chemical agents rapidly enough to implement effective mitigation measures. For example, a sensor capable of identifying the presence of *Bacillus anthracis* spores or *Cryptosporidium parvum* oocysts in a water-supply system would be beneficial for mitigating the consequences from either a terrorist attack or a potential natural phenomenon. Many water suppliers have noted that such a sensor should be inexpensive, but highly reliable, to promote its use in the field.

Researchers need to focus immediately on detectors that sample water continuously for the agents of interest. Of course, similar devices are needed for air sampling, but the problems are different. It is uncertain whether current antibody-based sensors have adequate sensitivity or speed. Antibody sensors also have problems with degradation over time. Current technology allows reasonable sensitivity (approximately 104 cells per milliliter) detection in about 10 minutes and some quantification. However, this technology has not yet been applied effectively to biological agents.

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[1] All years referenced in this document are fiscal years.

One example of research under this topic is the development of new technologies for rapid detection of contaminants of concern (e.g., anthrax, botulinum toxin, VX). This type of detector could routinely monitor a water-supply system or test a system suspected of being biologically or chemically contaminated. Another component of this research is tracking contaminants as they move through the water distribution system. Development of computer models for this purpose, supplemented by various measurements, is another component of this research.

Another area for study is the development of improved detection systems for monitoring the chlorine levels in water-supply systems. Such research would be based on the premise that terrorists could decide to de-chlorinate the water before introducing biological or chemical contaminants. Continuous monitoring of the chlorine level could alert water suppliers to potential terrorist activities.

Goals and Challenges

The goal of this research is to develop detectors for materials of interest, such as biological and chemical warfare agents and toxins. These detectors must be sensitive, fast, inexpensive, and quantitative. A challenge is that each of these characteristics is beyond current technology for biological agents. Current biological detectors are insensitive, slow, expensive, and generally nonquantitative. Instruments are available for detecting particles, but they are not able to differentiate between benign, suspended material and biological agents. Sensitive and quantitative systems are also available for chemical analysis; however, they are generally expensive, and detection is slower than real time.

Rationale for the Research and Desired Results

Many experts are concerned that few, if any, of the currently available detectors are capable of meeting the needs associated with biological and chemical agents. Research conducted in this area would be directed at developing a set of detectors appropriate for the various needs associated with biological or chemical agents.

Timeframe and Resource Requirements

Research for developing the instruments needed to detect biological and chemical agents in water-supply systems would occur from the present time through 2010. In the near-term (before 2002), researchers would conduct an extensive and detailed evaluation of ongoing R&D programs to determine which programs are relevant to this specific R&D topic. Their evaluation would include looking at basic science programs that have potential application in water-supply systems. R&D would also be conducted to adapt current detectors for use with biological and chemical agents of interest. These goals could be completed in two to three years. The estimated cost is approximately $30 million.

Beginning around 2003 and lasting for about three years, researchers would work to improve the sensitivity of the detectors so that they could detect agents in lower concentrations than is currently possible. Flow-through technologies in these detectors would be improved to allow real-time measurements. Researchers also would develop completely new, more sensitive detectors. Among the possible improvements in detector technologies to be examined are the use of novel excitation molecules, different sensor mechanisms, and engineering the receptor molecules to a solid-phase sensor. Funding requirements are estimated to be approximately $45 million.

From about 2006 to 2010, researchers would continue to develop new detectors to meet more stringent requirements associated with newly identified agents. Research also would be directed at those new requirements. The estimated cost for these efforts is $55 million.

3.1.3 Supervisory Control and Data Acquisition Systems

Description

Supervisory Control and Data Acquisition (SCADA) systems are used routinely to monitor and control water-supply systems. They consist of an interconnected array of instruments, monitors, control mechanisms, and panels that provide information to system operators and allow them to regulate the water flow, adjust purification systems, and generally control the quantity and quality of the water flowing into and through the system. Tens of thousands of SCADA systems are used for water-supply systems in the United States; however, they have different levels of sophistication and security.

An R&D plan for SCADA systems requires researchers to examine all components of such systems, including the individual sensors and other instruments, the data transmission and storage mechanisms, the control systems, and the security levels (or lack thereof). Once recommendations have been made for improving the security of SCADA systems, a series of pilot projects would be designed to demonstrate the effectiveness of the improved security efforts.

Goals and Challenges

The principal goal of this research is to develop protocols for designing and implementing SCADA systems that integrate measures for preventing intrusions or disruptions that could severely affect water-supply systems in the United States. Part of the R&D would focus on pilot testing or demonstrations of SCADA systems that have been developed under such protocols.

One of the major challenges for researchers in this area is the vast array of SCADA systems in the United States. These systems have a variety of designs and functions. The design and conduct of research programs must reflect these differences.

Also, research must be conducted to reduce vulnerabilities in SCADA systems in the most effective way.

Another challenge is to account for the numerous interfaces among different SCADA systems throughout the water-supply network. A gallon of water is potentially monitored and controlled by many such systems as it flows from its source to the end user. Such systems can include those used for extraction, piping, treatment, storage, distribution, and other processes. The degree of coordination and correlation at these interfaces undoubtedly varies greatly, and the challenge is to design and conduct a research program that not only addresses security issues at these interfaces but also accounts for their differences.

In some cases, water-supply systems are integrally connected with other critical infrastructures. For example, many water sources are associated with the generation of hydroelectric power. Water-based transportation could also be affected by operations of the water-supply infrastructure. For those cases in which two or more SCADA systems are involved, or in which a single SCADA system monitors and regulates the operations associated with more than one infrastructure (e.g., hydroelectric power and water supply from a dam and reservoir), the challenge is to conduct a research program that integrates all the interconnected needs of such systems.

Rationale for the Research and Desired Results

The large number of SCADA systems in the water-supply system creates various vulnerabilities for cyber intrusions. The rationale for conducting research in this area is to develop methods that reduce opportunities to disrupt the water-supply system through attacks on SCADA systems. The research program for water-supply SCADA systems would provide:

- A means to identify vulnerabilities in SCADA systems;
- A means to identify vulnerabilities caused by interfacing of the various SCADA systems along the water-supply pathway;
- Techniques for rectifying identified vulnerabilities; and
- A set of protocols for developing SCADA systems that are more secure, both within themselves and at the interfaces of different systems.

Timeframe and Resource Requirements

Near-term (before 2002) work on this R&D topic entails the development of vulnerability assessment criteria and techniques for SCADA security and systems. These activities could be completed in approximately three years at a total cost of $15 million. From 2003 to 2005, researchers would focus on developing (1) techniques to rectify security problems and (2) preliminary protocols for the design and operation of secure systems. These efforts would cost about $15 million. Initial pilot testing of more secure SCADA systems also would be done. Finally, from approximately 2006 to 2010, researchers would conduct additional pilot tests and demonstrations. Lessons learned would be integrated into a final set of design and operational protocols. The cost for this research is estimated to be $25 million.

3.1.4 Vulnerability Assessment of Water-supply Systems

Description

Another area for R&D is development of methods for finding and evaluating cost-effective options to reduce vulnerabilities of water-supply systems. This R&D effort would include establishing vulnerability criteria, developing information on possible ways to reduce these vulnerabilities to physical and cyber attacks, and developing tools to assist in determining which of the potential options are most cost effective. A series of pilot tests would also be conducted as part of this research effort. Some level of training would be required to allow water-system operators to conduct these evaluations.

Goals and Challenges

This research would produce cost-effective methods, information, and tools that could be used to reduce the vulnerability of water-supply systems to physical and cyber threats. Challenges include the significant number of water-supply systems in the United States, the diversity of these systems with regard to their capacity, location (e.g., municipal, rural, mountainous terrain), physical design characteristics, age, and other design and operating parameters. The variety of potential terrorist threats and vulnerability-reduction options also adds to the challenges of this research topic.

Rationale for the Research and Desired Results

As discussed in Section 2.2 of this report, only a limited number of U.S. water-supply systems have been examined with respect to their vulnerabilities to terrorist attacks. However, the consensus is that many systems are, to various degrees, vulnerable to physical or cyber attacks. To assist decision makers in taking steps toward reducing these vulnerabilities, it is necessary to develop an appropriate information base and standards against which to evaluate the vulnerabilities of water-supply systems as they currently exist. These same standards could then be used to evaluate the effectiveness of options for reducing any vulnerabilities. R&D on this topic would yield the appropriate information base and evaluation tools upon which to base such decisions. A key component of this research would be developing and implementing pilot projects to demonstrate the effectiveness in evaluating vulnerability-reduction options. It is significant that a representative of New York City has informally offered that their water-supply system be a part of any pilot projects dealing with this issue.

Timeframe and Resource Requirements

In the near-term (before 2002), researchers would develop criteria for evaluating vulnerability-reduction options. This activity can be accomplished at a cost of approximately $9 million. Characterizing some vulnerability-reduction process/practices also would occur. Developing evaluation methods and tools would be conducted in the next three years (2003–2005). Methods and tools would be pilot tested and validated on a number of water-supply systems. The cost is estimated to be $12 million for these efforts. Finally, from about 2006 to 2010, research would be directed toward applying lessons learned from the pilot tests, enhancing the information base and evaluation methods, and performing additional validation. The estimated funding requirement for these efforts is $16 million.

3.1.5 Center of Excellence for Risk Assessment of Water-supply Systems

Description

As the threat of terrorist activities aimed at water-supply systems increases, responsibilities of municipalities and other operators of these systems must expand to include greater involvement and investment in security. This change will create additional demands on these owners/operators — far beyond what they have traditionally faced. To assist in conducting vulnerability assessments, selecting protection or mitigation measures, and understanding the operational and risk impacts of various contaminants, a Center of Excellence for Risk Assessment of Water-supply Systems should be established as an R&D topical area. This center would call on experts in vulnerability assessment, toxicology, risk assessment, computer security, and other areas. They would conduct appropriate research, develop methods and models, characterize data on biological and chemical agents, and conduct other analyses and support services to help protect our water-supply systems. A “hot line” to the center would be established to respond to inquiries concerning the protection of water-supply systems. It may be possible to leverage DoD’s existing chemical/biological help and hot lines.

The center would perform city-specific vulnerability and risk analyses for a number of “pilot” water-supply systems to establish standard methods for evaluating those systems. Initially, numerical models would be used to assess system vulnerability, to identify optimal monitoring locations, and to define operational procedures to be followed if a water-supply system is degraded by naturally occurring or human-initiated events. With additional experience and time, subscale testing of important processes should be performed; finally, real systems should be tested when incidents occur.

The center would serve as a repository for data collected by means of geographical information systems (GISs). These data would be used to characterize and analyze water-supply systems, as well as biological and chemical agents, and to evaluate system vulnerabilities and risks. The center would communicate with water purveyors if a system failed or was attacked by terrorists. Experts in water quality, mitigation, and other areas would be available for consultation with local staff at a water-supply facility to minimize adverse effects.

Once the center and some of its capabilities have been established, a series of pilot tests would be conducted to demonstrate the effectiveness of the center in responding to potential emergencies in water-supply systems. Lessons learned during these pilot tests would be beneficial in refining the center's capabilities and any associated models and information developed to support its activities.

Goals and Challenges

The basic goals of this research are as follows:

- Establish a core of "networked" experts to develop and apply analytical models and methods for protecting water-supply systems.
- Develop and provide information on various biological and chemical agents that can be retrieved by operators of any water-supply system in the United States.
- Provide a means for communicating information on threats, mitigation options, and other areas of interest in the security of water-supply systems.
- Develop plans for responding to natural disasters, system failures, terrorist attacks, or any other threat that places the water system or the people it serves at risk.

An important goal of this R&D program is to develop a working relationship between the center and the water industry. Organizations, such as the American Water Works Association, could help to facilitate such relationships. Among the benefits of a mutually respected and trusted relationship is the advancement of the concept that threats to water-supply systems are real and that financial investments to address them are of merit. Industry support would help to move the R&D beyond merely academic interest and into real-world applications. Another benefit of such a relationship is the establishment of standards for the release of research results that might also be of value to potential terrorists.

Challenges include addressing the many types and sizes of water-supply systems and providing a means for real-time communication of system conditions so that appropriate actions can be identified and communicated to operators of the affected water-supply system. Routine testing to ensure proper and timely operation is also a challenge in the development and operation of the center.

Rationale for Research and Desired Results

If a natural disaster, system failure, or terrorist attack occurred, contingency plans must be in place to minimize adverse impacts. Coordinating various agencies, such as police, fire, and medical, is crucial to successful mitigation. Although many cities have established contingency plans for natural disasters and system failure, few cities have response plans for terrorist activities; however, in many cases, plans currently available could be used (or adapted) for use in such incidents. Assessment methods and tools need to be established, and basic information on the characteristics of potential biological and chemical agents needs to be developed. Means for communicating information to appropriate parties must also be established. Standards for vulnerability assessments, mitigation effectiveness, and other metrics of importance must be developed. These standards would assist individuals who have assumed security responsibilities in addition to their responsibilities of ownership and operation of systems.

A Center for Risk Excellence would help to provide information efficiently to water-supply system operators regarding risks they face and appropriate responses to those risks. Information would be developed and placed in a format and medium appropriate for on-line use by water-system operators. Methods and tools would also be developed, tested, applied, and distributed through the center.

Timeframe and Resource Requirements

The Center for Risk Excellence could be established within approximately six months and produce initial results shortly thereafter. The start-up and operating costs for the near-term (before 2002) are estimated to be $8 million. From 2003 to 2005, the center would collect, assess, and distribute information; develop, verify, and apply models; develop response plans; and perform other activities. Funding for these efforts is estimated to be $9 million. Finally, researchers would re-examine the role of the center and define its long-term objectives and the most effective methods for accomplishing them. Funding needed for these activities (2006–2010) is estimated to be approximately $11 million.

3.2 Emergency Services

Research and development activity in emergency services has not kept pace with the growing number of contaminants that this infrastructure will potentially encounter. First responders have expressed a need for real-time detection systems, for personal protective equipment, and for ways to manage emergency situations that arise from biological or chemical contaminants. In-depth and continuous training in dealing with practical situations must be provided for all emergency response personnel, including supervisors. Treatment methods and techniques for providing appropriate antidotes are also insufficient.

Several specific research projects have been identified and discussed in earlier work done of behalf of the Commission. Examples of these projects include Modernization of Emergency Services Training and Exercises, Safe and Resilient Communities, Improved Evacuation Modeling, and Vulnerability of the U.S. Economy to a Catastrophic Disaster. Other R&D projects include those conducted at Natrick Laboratories through the Defense Advanced Research Project Agency and the U.S. Army Soldiers Systems Command. The Commonwealth of Massachusetts and the City of Boston are establishing Cooperative Research and Development Agreements with Natrick Laboratories to address the issue of inadequate personal protection equipment for local first responders.

The Vital Human Services R&D Roadmapping Team has agreed that some of these projects could help significantly to improve the protection of this critical infrastructure. However, these projects are more specific than the R&D topical areas being developed in this effort. The Roadmapping Team therefore elected to consider the following R&D topical areas.

3.2.1 Detectors and Detection Systems for Emergency Services

Description

As noted earlier, the need for detectors and associated systems for addressing biological and chemical agents is increasing. Emergency services require improved detection on several fronts: detecting an initial incident; protecting responders; treating injured or ill individuals; and decontaminating the affected areas or individuals. In each area, detection requirements must be established and instrumentation developed. Existing programs, such as the Chemical Warfare Response Improvement Program established under the Nunn-Lugar-Domenici Domestic Preparedness Program, need to be leveraged.

The activities in this area involve both basic and applied research. Basic research includes developing detectors for additional biological and chemical agents and developing means to improve the response time of existing detectors. Research into the development and/or adoption of robotic technologies also would be a major component of this program. Applied research includes the adaptation of existing detectors and detection systems to the requirements of the emergency services infrastructure.

Goals and Challenges

The goal of this research is to develop a set of detectors that can be used in response to biological and chemical incidents. These detectors must be sensitive, fast, fairly inexpensive, rugged, and quantitative. In addition, they must be insensitive to heat, cold, smoke, dust, and water.

Numerous challenges must be overcome to develop an appropriate detector for first responders. Such challenges include identifying the targets that the detector should recognize. This list of targets should include, but not be limited to, blistering and nerve agents, biological toxins, and biowarfare agents (including bacteria and viruses). Because of the large disparity among these materials, developing a common analytical system would be challenging. The elimination of false positive responses is a significant challenge and goal of this research.

Some researchers believe that a time-of-flight mass spectrometer used for detecting chemical warfare agents could be applicable in detecting biological agents. However, this large, complicated instrument requires considerable expertise to run. Data analysis is also extremely complex. The first R&D hurdle is to overcome these limitations. The second is to miniaturize the detector and strengthen it to withstand the rigors of the environment and handling commonly encountered by fire fighters, police officers, and EMTs.

Another goal of this research is to provide local first responders with adequate personal protective equipment. For example, there is no known U.S.-developed personal protective equipment that is a combination first responder bomb suit that is also encapsulated to standards appropriate for biological or chemical protection. Current research to achieve both types of protection have produced cumbersome and ineffective equipment. A challenge in this research is to integrate various types of detection into personal protective equipment rather than having separate systems for detection and protection.

Rationale for Research and Desired Results

Detection equipment at the present time (1998) is inadequate and in very short supply. Enhanced detection systems must provide information and protect emergency services personnel (e.g., provide fast response information to fire protection personnel before they enter a location suspected of being contaminated with biological or chemical agents). Thus, research areas are (1) development of a joint biological/chemical detector, (2) miniaturization of the unit, and (3) association with a heads-up display unit. Development and adaptation of robotic technologies to emergency services applications also are required to conduct emergency response activities effectively while protecting first responders to the fullest extent feasible. R&D in this area should produce a set of detectors appropriate for a range of emergency response applications and a set of robotic technologies that are useful in the emergency service infrastructure.

Timeframe and Resource Requirements

Developing a set of detectors that covers a range of emergency services needs is likely to be an ongoing process. As new contaminants are discovered (or invented), it will be necessary to have corresponding detection capabilities. For preliminary roadmapping, requirements for the known contaminants probably could be developed in the near-term (before 2002). Preliminary investigations into the expanded use of robotic technologies in the emergency services infrastructure would also be conducted during this period, as well as some basic research into new detectors. The estimated cost for this near-term effort is approximately $30 million. Research in both the basic and applied areas would continue from approximately 2003 through 2005. Funding needs are estimated to total $45 million, as a new slate of requirements and detectors would be investigated. Finally, from 2006 to 2010, most of the research would focus on applications. The estimated cost for these efforts is approximately $55 million.

3.2.2 Integrated Emergency Management System

Description

Research in this area would focus on developing an integrated emergency management support system consisting of a set of analytical tools for defining prototype systems. These prototypes could:

- Create a systematic organizational protocol and standard operating procedure for intergovernmental and interagency coordination and cooperation that involves all levels of government at the federal, state, and local jurisdictional lines of authority.
- Anticipate, indicate, and warn (in specific cases) the proper authorities of the time and location of events that could trigger emergencies;
- Create templates for use by data collectors;
- Identify members of crisis management teams and establish an "Incident Command System";
- Determine the importance of economic, social, climatological, military, and political data; develop tools to analyze these data to provide predictive capability;
- Develop a categorization scheme to describe the type of crisis; and
- Identify diplomatic, informational, economic, and military responses to crises and their potential for mitigating these crises.

This research would include examining and evaluating existing support systems used in the military and private sector to determine their applicability to a more comprehensive integrated emergency management system. It would also include the development of educational programs to inform the general public of the appropriate response(s) to potential biological or chemical incidents.

Goals and Challenges

A set of tools should be developed that characterizes and defines appropriate responses to a crisis. These tools could include statistical analysis packages, image analysis capability, and artificial intelligence-based expert systems. They could be interfaced with network functions through templates that guide data collection. Moreover, they could be linked to a series of output generators that would classify crises, generate scenarios, and assemble crisis teams. The R&D effort should also include stakeholder/user identification and involvement, characterization, classification, and analysis. Workshops, pilot studies, and multiagency training are needed to ensure support from stakeholders. As emergency situations arise, the appropriate components of this system could be pilot tested, and lessons learned would be used to improve the system. These pilot tests would also provide opportunities to illustrate the value of such a system to emergency responders, decision makers, and stakeholders.

It would be a challenge to develop systems appropriate for the full scope of possible incidents and for the range of localities potentially impacted. Smaller cities and towns would be likely to look to larger cities for assistance, and this probability should be integrated into developing these management support systems.

Rationale for the Research and Desired Results

Currently, no tool can perform all the functions required of such a system. This system would be useful in planning, training, mitigating potential incidents, and responding to incidents more expeditiously and in a coordinated manner. A critical need is to develop an interoperable and integrated telecommunications infrastructure for intergovernmental and interagency coordination. This need arises because many first responders to an incident cannot communicate with each other via radio. Likewise, many adjoining local jurisdictions and the various levels of government cannot communicate with each other in a single secure interoperable telecommunications system.

Results of this R&D topic are expected to include the establishment of protocols for creating and evaluating response options during a given set of emergencies (e.g., natural disasters, technological failures, or man-made crises). These options would consider the response policies of various agencies, their practices, and the application of new technologies to help in mitigating consequences or in performing recovery operations. Development and evaluation of recovery options would also be considered in this research topic. Results from this research would help decision makers determine how to respond to, or recover from, such incidents. For example, results could assist decision makers in responding to a release of agents in subterranean public transport systems (e.g., deciding whether the system should be vented or closed or whether a new containment mechanism is needed). Another result of this research would be a means of identifying areas of greatest impact so that mitigation measures can be taken before an incident occurs. For example, certain antitoxins could be stored near, rather than at, facilities that could be highly vulnerable to attack.

Timeframe and Resource Requirements

Initially, in the near-term (before 2002), requirements would be specified, and the development of tools would be initiated. Existing support systems would be evaluated and the appropriate capabilities adapted for application to the more comprehensive system being developed. Funding required for these efforts is estimated to be about $13 million. In the following efforts (from about 2003 to 2005), pilot tests would be conducted, lessons learned would be incorporated, and a final set of tools would be developed. Funding required for these efforts is estimated to be about $15 million. It is possible that only one or two years would be required to complete these tasks. Finally, the cost for any necessary additional research is estimated to be $5 million.

3.2.3 Multihazard, Real-time Simulation and Modeling

Description

Research would be conducted to develop methods to upgrade models that simulate hazards and protective actions to incorporate real-time data on hazard and response conditions. Techniques for presenting the results of these models in ways that are meaningful and useful to emergency managers and decision makers would be researched.

Goals and Challenges

Existing simulation models for emergency response often are useful only in the pre- and post-event phases of emergency management. Models of hazards (e.g., radiological or chemical dispersion) and of protective actions (e.g., evacuation) are best suited for pre-planning emergency responses, for creating plausible exercise scenarios, and for reconstructing and analyzing events. Their usefulness in real-time emergency response is limited, and research would focus on each of these limitations:

- *Real-time data are not available*. Technologies exist for collecting some real-time data (e.g., meteorological data, sensors for traffic volume) and transmitting those data to centralized locations. For example, meteorological data at chemical stockpile storage sites are used to update the Army's atmospheric dispersion model every 15 minutes. In Los Angeles, traffic sensors on freeways constantly feed real-time data to a centralized monitoring point. However, the availability of such technologies nationwide is far from complete, primarily because of cost and incompatible systems.

- *Manual data entry is time consuming*. Some background data needed by these models (e.g., highway network configuration, terrain, and topography) are not available from automatic sensors. Some efforts have been made to generate these data from GIS, using, for example, the Census Bureau's TIGER/Line files and U.S. Geological Survey's digital topography data. However, such efforts to date have required extensive manual editing to clean up or reformat the data.

- *The presentation of model results frequently fails to meet the needs of emergency managers and decision makers.* In general, existing technologies are adequate for displaying the results of models graphically (e.g., a plume overlaid on a local area map or "Thermometer bars" along roadways on a map to indicate traffic volume). However, the meaning of the results often is unclear to emergency managers and decision makers. For example, they might need to know the underlying assumptions that led to a set of results or what might happen if the assumptions changed. They usually need to know the implications of the results for the actions they take.

- *Data need to be accessible and secure.* Accessibility and security of data collection, distribution, and use is critical.

To ensure a high level of confidence in the use of such models for real-time response, the R&D efforts must include extensive validation and training. Furthermore, emergency managers and decision makers must be able to use these models in planning and training. As with several other R&D topics, true emergency situations provide opportunities for pilot tests. A significant challenge would be to develop simulation models that meet the above criteria but that are not cost prohibitive in terms of initial purchase price, the collection of data needed to conduct the simulation, or in the training of people to conduct the analyses.

Rationale for the Research and Desired Results

Reducing the cost of technologies for real-time data collection increases their availability for real-time simulation modeling. Automating the translation of data from sources into input streams needed by simulation models would make using such models feasible and allow a shorter turnaround time. Meaningful presentation and display of model results would make these models more practically useful in real-time emergency response, increasing and enhancing the real-time information available to decision makers.

Timeframe and Resource Requirements

Initially (before 2002), system requirements would be defined, and development of a prototype system would be initiated. Emergency response personnel and decision makers would be consulted to identify their needs. Existing analytical tools would be evaluated for their application to this system. Funding required for these efforts is estimated to be $17 million. From about 2003 to 2005, the prototype systems developed earlier would be pilot tested under actual emergency conditions. Results from these pilot tests would be factored into model revisions. Funding for these efforts is estimated to be $21 million. Finally, from approximately 2006 to 2010, additional pilot tests would be conducted, and a final set of models developed. These models would be distributed to appropriate organizations and agencies within the emergency services infrastructure. Funding required for these efforts is estimated to be $23 million.

3.2.4 Behavioral/Psychological Studies of Reactions to Incidents

Description

Behavioral/psychological studies to determine public and emergency responder reactions to nuclear, chemical, and biological incidents would be performed. Research would address the following questions:

- Would hospitals be overwhelmed by public demand for care following an incident? For instance, would the public view common symptoms to be related to exposure to biological or chemical agents?

- Would monitoring and decontamination facilities be overwhelmed by public demand?

- Would large “shadow” effects of the public occur outside affected areas; that is, would people take protective actions, such as evacuation, on their own, thereby hindering response actions in affected areas?

- Would the public comply with protective actions recommended by authorities? For instance, would the public follow their instinct to “flee” (that is, evacuate) rather than to shelter in place, which might be the safer action?

- If evacuation is ordered, would the public drive in a cooperative manner, which has been documented during other hazards (e.g., hurricanes), or more erratically (e.g., driven by fear)?

- Would first responders stay or abandon their jobs to care for themselves or their loved ones?

- What would be the implications of these behaviors in such areas as crowd control, resource planning, and communication of emergency information and instructions?

Goals and Challenges

Because there is not a base of experience from actual events, research of this type is necessarily hypothetical. Subjects may be asked, “What would you do if an incident were to happen?” But their responses to hypothetical questions may differ from their behavior during an actual incident. A basic goal of this research is to enhance the probability that emergency services personnel would perform their duties as planned and with the expected level of efficiency and effectiveness. Integrating the results of this research into appropriate training modules and decision making is both a goal and a challenge of this research.

A significant challenge for this research is dealing with the wide spectrum of potential events (e.g., natural disasters, technological failures, terrorist actions). This diversity is complicated by the range of possible consequences (e.g., release of different quantities of biological contaminants) and the time available for appropriate response (ranging from little or none for some types of emergencies to days or weeks for others). Another challenge is to meet the needs of the wide range of training and experience of first responders and other emergency services personnel. Some are full-time professionals, whereas other are part-time volunteers.

Another challenge would be to integrate additional training for first responders into existing training requirements and practices. For example, first responders are being taught through the DoD Domestic Preparedness courses under the Nunn-Lugar-Domenici Act of 1996 and the Department of Justice Bureau of Justice Assistance Program courses under the Death Penalty Act of 1996. Such training courses must be recognized when developing additional means of training for first responders.

Rationale for the Research and Desired Results

Some work is underway to train public authorities in identifying the risks from biological and chemical incidents and to communicate those risks to the public. Questions about public and emergency worker reactions have been studied extensively for more common hazards, such as hurricanes and “ordinary” hazardous materials incidents. However, it is unknown to what extent the findings from those studies carry over to biological and chemical incidents, which involve less familiar hazards and a higher “fear factor.” It is anticipated that this research would result in methods to anticipate public and emergency worker reactions. This knowledge would enable public authorities to improve their emergency response plans and to better communicate information and instructions to the public.

Timeframe and Resource Requirements

In the near-term (before 2002), researchers would develop a baseline of anticipated and required responses through a series of subject interviews, surveys, and evaluations of historical events. Funding required for these efforts is estimated to be $6 million. From approximately 2003 to 2005, researchers would develop and conduct a set of training courses to help assure that emergency services personnel would respond appropriately and efficiently to emergencies. Techniques for improved response through enhanced communications both before and during an emergency would be developed and pilot tested. Funding required for these efforts is estimated to be $6 million. An additional year or more could be required to complete this research. The cost for this extra research is estimated to be $2 million per year.

3.2.5 Decontamination Technologies

Description

Under this R&D topic, technologies used for decontaminating structures and equipment (contaminated with biological or chemical agents) would be identified and characterized. As needed, the R&D would include developing new, more effective technologies. Protocols also would be established to help select the most appropriate technology for any situation.

Goals and Challenges

The basic goals of this research are to identify and characterize decontamination technologies that can remove biological or chemical contamination effectively and to develop a set of decision criteria to be used in selecting the most appropriate technology for a situation. Another goal is to develop such technologies for use in situations where decontamination technologies are not effective. It is probable that some of the technologies identified or developed under this research would be appropriate for other critical infrastructures. Pilot testing of decontamination technologies is a significant component of this R&D topic.

This research offers many challenges, including the wide spectrum of biological and chemical agents, the large variations in the physical design and construction materials used in the affected infrastructures, and public perceptions regarding contaminated materials and the level of decontamination required before a system could be returned to service.

Rationale for Research and Desired Results

Following an event in which any part of an infrastructure has been contaminated, it is necessary to develop and evaluate decontamination options that provide for either dismantling and disposal of the infrastructure or for its return to service. Some situations, particularly those involving biological or chemical contamination, currently have few or no established protocols or cleanup criteria needed to make decontamination decisions. This research would be designed and conducted to provide a foundation upon which to base decisions regarding decontamination options, the level of decontamination that is appropriate for resumption of services, and dismantlement and disposal requirements.

The results of this research should include a list of current and emerging decontamination technologies; a characterization of these technologies, including their costs and effectiveness against various types of biological and chemical contamination; a set of protocols or procedures for conducting the decontamination technologies; a set of recommendations for dealing with the selection of a particular technology; and explanations concerning implementation and field testing of the technology.

Timeframe and Resource Requirements

In the near term (before 2002), R&D would focus on identifying and characterizing technologies that currently exist or are nearly fully developed. A preliminary set of decontamination needs also would be developed, as well as some basic requirements in regard to the decision processes. Construction and operation of necessary research facilities would be initiated. Funding required for these efforts is estimated to be $55 million. Efforts up to 2005 would focus on developing new decontamination technologies. Some new technologies should be available for demonstration by the end of this term. A final set of protocols for selecting technologies would be completed. The estimated cost for these efforts is $75 million. Before 2010, additional technologies would be developed and readied for general use. It is also anticipated that requirements for new technologies (e.g., to address an expanded set of biological and chemical agents) would be developed, and R&D on a new set of technologies would begin. Estimated costs for these efforts are $105 million.

3.2.6 Systems Analysis of Public Health Emergency Response Systems

Description

Research under this topic would identify (1) critical elements and nodes, (2) linkages (i.e., critical paths) between these elements, and (3) vulnerabilities or failure points that place the world's populations at risk to natural (i.e., pandemic) or man-made (e.g., biological weapons of mass destruction) emergencies. This research would help to link the existing worldwide surveillance of contagious diseases to quick responses to contain, treat, and eradicate these diseases and prevent the rapid proliferation of epidemics. The systems analysis would begin with a detailed component analysis to identify all of the elements of concern. The following concerns, however, would be among the first to be examined:

- *Threat assessment.* The research would examine the ways by which patients are diagnosed with contagion and how biological agents are identified.

- *Information linkages.* How do professionals in the medical community communicate and link information resources?

- *Manufacture of vaccines and antidotes.* Many suppliers involved in the manufacture of medical supplies and vaccines are foreign or multinational companies; hence, the United States may not have the authority to direct the manufacture and distribution of their products.

- *Stockpiling of vaccines and antidotes.* Prerequisites and limitations to the production of vaccines and antidotes require that they be stockpiled for use in an emergency.

The systems analysis effort would seek to bring together federal, state, and local public health emergency response R&D needs. To accomplish this goal, it is necessary to categorize the roles and missions of agencies that support public health epidemiological decision making. This work would identify the political interests and technical concerns at various levels of decision making.

A second component of this research would examine alternative medical treatment methods and systems that could be implemented if existing medical systems and practices became overwhelmed by natural epidemics or terrorist biological and chemical assaults. For example, the need for respiratory ventilators would far exceed hospital supplies if an episode such as the sarin nerve agent attack in the Tokyo subway were to occur in a U.S. city. Another example would be the need to decontaminate large numbers of victims exposed to biological or chemical agents as the result of such an incident. What alternative methods, equipment, or resources could be used to extend the capacity of the medical response under such emergency conditions? The following lists potential areas of concern where normal channels of emergency response and patient treatment could be overwhelmed and workable alternatives may be needed to cope with a large-scale emergency:

- Patient isolation,
- Respiratory therapies,
- Decontamination,
- Emergency worker protection, and
- Multiple hazard (e.g., biological and chemical) response.

These and other areas would be examined, and alternative response methods would be developed. Researchers would investigate, characterize, catalog, and inventory in a database, alternative treatments that could be used in an emergency to treat large numbers of victims. It is not possible to predict with any degree of specificity, the types of alternative treatment strategies that would be needed in an emergency. Therefore, as a first step, it would be necessary to conduct a needs assessment. Emergency medical professionals would be interviewed and consulted to determine what equipment most likely would be in short supply and which workable medical alternatives would be needed in a national public health emergency.

Goals and Challenges

The basic goals of this research are to develop tools to assist in identifying threats and vulnerabilities to the public health emergency response systems and to develop and evaluate alternative means of meeting the needs of the public health system under extreme emergency conditions. These tools would assist in planning for terrorist or natural incidents that could otherwise overwhelm the existing systems.

Challenges include the number and diversity of emergency response and medical treatment organizations that respond to emergencies of the type considered in this research. The variety of potential emergencies and response requirements also creates a significant challenge. Potential lack of uniformity in existing equipment at medical treatment facilities also presents a challenge in identifying and developing alternative treatment options that could be used under the extreme conditions hypothesized here. As with other research topics, the challenge would be to integrate this topic with ongoing programs (e.g., a New York City program to identify the number of respirators, isolation units, etc., at the various medical care facilities throughout the city).

Rationale for the Research and Desired Results

A comprehensive systems analysis has been performed for the public health emergency response and decision-making system. This analysis is a vital first step in identifying gaps that need to be bridged to respond efficiently to natural or man-made public health emergencies. In addition, no systematic analysis and compilation of alternative methods, equipment, or resources can be used to extend medical response capacity under severe emergency conditions. Such a compilation of alternative treatment strategies would provide an important source of information for assisting the nation to respond to a pandemic or terrorist catastrophe.

Results of this research would include a set of analytical tools and procedures to be applied to medical treatment systems to identify vulnerabilities and potential solutions for extreme conditions. Also, a set of alternative treatment methods and practices to be used under such conditions would result from this research.

Timeframe and Resource Requirements

Near-term (before 2002) research would require $13 million to complete. Surveys of existing medical treatment capabilities would be conducted and work on developing systems analysis tools would be initiated. From 2003 to 2005, prototypes of analysis tools would be completed and pilot tested at various medical facilities. Lessons learned from these pilot tests would be factored in to improve analytical capabilities. A preliminary set of alternative treatment practices to be used in extreme conditions would be developed as would recommendations regarding the type of equipment needed to implement these alternatives. Preparedness exercises would be conducted to evaluate the ability of public health systems to adapt to the extreme conditions considered in this research. Funding required for these efforts is estimated to be $15 million. Research conducted during the 2006–2010 timeframe would finalize system analysis tools, databases, and other information needed for a comprehensive analysis of public health emergency response systems. Additional information on alternative treatment practices would be developed and distributed, and additional preparedness exercises would be conducted. Funding required for these efforts is estimated to be $17 million.

3.3 Government Services

Government services are strongly linked to the other critical infrastructures (e.g., water supply and pressure for fire fighting, roads and bridges for emergency response vehicles, and telephone service for communications between the public and appropriate government agencies and personnel). Thus, many of the R&D topics described in Section 3.2 (emergency services), most of the topics identified in Section 3.1 (water-supply systems), and many of the topics noted elsewhere for other critical infrastructures also apply to government services. Reasons for these overlapping research needs include:

- The large degree of interdependence of government services with other critical infrastructures; and
- The complexity of government services (e.g., the multitude of services provided by governments and the numbers and locations of people receiving these services).

The Vital Human Services R&D Roadmapping Team did, however, identify one R&D topic that would focus almost exclusively on government services. This topic is presented below.

3.3.1 Support Systems for Reconfiguring Government

Description

During and following an emergency that involves full or partial loss of government services, it is vital to re-establish these services as expeditiously as possible. Research would focus on designing and implementing a support system to prioritize reconfiguration options, to examine vulnerabilities in the reconfiguration process, and in general expedite the recovery process. A series of pilot tests would be conducted to validate and improve the models and information comprising this support system. The research would complement activities directed toward issues such as succession planning, reconstitution of services, and other military and civilian efforts focusing on government services.

Such a support system (or perhaps a family of systems) would be based on a pre-determined set of priorities for various government services. The system would contain information on the responsibilities and capabilities of all levels of government (local, county, state, and federal) so that if some or all of these services are disrupted, a plan for re-establishing services could be developed and implemented quickly. A major focus of this research would be to establish priorities for reconfiguring government functions. These priorities would depend on the type and degree of services lost, the nature of the emergency causing the loss of services (e.g., natural or man-made), and other parameters to be evaluated in the support systems.

Goals and Challenges

The goals of this research include developing and testing a set of systems designed to assist in reconfiguring government services following emergencies. As actual disasters or drills occur, a set of pilot tests could be developed to validate the models and decision methods that are built into the support systems. Another goal (and a challenge) of this research would be to integrate a reconfigured government with the recovering business and industrial sectors. It may be desirable to obtain public and private-sector concurrence on a timetable for reconfiguring essential services so that the highest priority needs of each sector are met.

One of the major challenges of this R&D effort would be to establish a knowledge base appropriate for recovering government services. Most experience-based information comes from normal conditions or from partial, typically localized, disruptions. Another challenge would be to recognize and characterize the multitude of services provided by various government entities. It is likely that differing priorities among the various levels of government would surface regarding the re-establishment of the various types of service. One of the challenges would be to develop a set of protocols to follow within a support system.

It would be a challenge, in developing a support system of this type, to integrate each of the other infrastructures and their changing status into the government reconfiguration process. Another challenge would be to develop a support system that acknowledges the spectrum of potential disasters; that is, a system that applies to disasters that are geographically limited, such as those from hurricanes; from a targeted attack on certain components of government throughout the United States; and from a more general attack in which not only government services, but also other critical, interrelated infrastructures are affected.

Rationale for the Research and Desired Results

The rationale for conducting this research is to assist in reconfiguring government services efficiently and appropriately. Restoring government services would give the public confidence that the nation could recover from any disaster. Furthermore, it would help to restore selected government services (e.g., military protection, national guard, police and fire protection, and medical services) that are required for responding to an ongoing emergency.

Researchers would develop a support system (or set of systems) to aid in recovery operations. Data and other information needed to facilitate such a recovery also would result from this research. Experience gained during pilot testing of the support system would be another valuable result.

Timeframe and Resource Requirements

The timeframe and resource requirements for this R&D topic have been estimated for three timeframes. In the near term (before 2002), basic requirements for this system would be defined and a limited prototype system developed. The funding required for this phase is estimated to be $10 million. From 2003 to 2005, a more robust prototype with additional components would be developed and pilot tested. The cost for these efforts is estimated to be $12 million. Finally, a full system would be developed and tested. The cost requirement for these efforts is estimated to be approximately $16 million.

3.4 Summary of R&D Topics

The R&D topics identified by the Vital Human Services R&D Roadmapping Team are summarized in Table E.1. These topics provide a foundation for research to enhance protection of the water-supply systems, emergency services, and government services in the United States against threats posed through physical or cyber actions or through the inherent complexities and interdependencies of the infrastructures themselves.

Table E.1 Summary of Research Topics for Vital Human Services[a]

No.	Research Topic: Title (Type[b])	Product	Goals and Challenges	Threats and Vulnerabilities	Priority Category
	Water-supply Systems				
1	Identification and Characterization of Biological and Chemical Agents (B, A)	Data, information	Quantify risks and impacts; large number of agents.	Physical, complexities	Most important
2	Biological and Chemical Agent Detectors (B, A)	Detectors	Develop inexpensive, sensitive, fast, quantitative detectors.	Physical	Most important
3	Supervisory Control and Data Acquisition Systems (A)	Design protocols	Multiple systems; interdependencies.	Physical, cyber, complexities, interdependencies	Most important
4	Vulnerability Assessment of Water-supply Systems (A)	Information, methods, tools	Number and diversity of systems; range of options; buy-in by owners/operators; validation.	Physical, cyber, complexities, interdependencies	Most important
5	Center of Excellence for Risk Assessment of Water-supply Systems (B, A)	Methods, information	Establish point of contact for information on threats and vulnerabilities; identify diversity in needs of water-supply systems.	Physical, cyber, complexities, interdependencies	Most important
	Emergency Services				
6	Detectors and Detection Systems for Emergency Services (B, A)	Detectors, robotics	Develop inexpensive, sensitive, fast, quantitative detectors.	Physical	Most important
7	Integrated Emergency Management System (A)	Software, information	Validation; stakeholder buy-in.	Physical, cyber, complexities	Very important
8	Multihazard, Real-time Simulation and Modeling (A)	Software system	Validation; response time; effectiveness.	Physical, cyber, complexities, interdependencies	Most important
9	Behavioral/Psychological Studies of Reactions to Incidents (A)	Information	Validation.	Physical	Important
10	Decontamination Technologies (A)	Technologies, information	Develop technologies, many facilities, many contaminants.	Physical, complexities, interdependencies	Most important
11	Systems Analysis of Public Health Emergency Response Systems (A)	Information; protocols for coordination	Assemble public health emergency response needs; different roles of agencies, many kinds of threats.	Physical, complexities, interdependencies	Most important
	Government Services				
12	Support Systems for Reconfiguring Government (A)	Models, data	Expedite reconfiguration of government following emergencies.	Physical, cyber, complexities, interdependencies	Very important

[a] The order of the R&D topics within a priority category (i.e., most important, very important, important) does not imply relative importance.

[b] B = basic; A = applied; ATD = advanced technology development; and POP = proof of principle and validation.

Section 4
R&D Topic Roadmap

The suggested roadmap for each of the R&D topics identified and presented by the Vital Human Services R&D Roadmapping Team is summarized in Table E.2. The accomplishments during the research timeframes (near term, before 2005, and before 2010) are summarized. More detailed information can be found in the individual topic descriptions provided in Section 3.

Table E.2 Summary of Vital Human Services R&D Roadmap

Research Topic No.	Research Topic Title	Near Term (Resource Estimate[a])	Achieved by ~2005 (Resource Estimate[a])	Achieved by ~2010 (Resource Estimate[a])
		Water-supply Systems		
1	Identification and Characterization of Biological and Chemical Agents	Characterize known agents. ($14 million)	Identify unknown agents and characterize their physical and chemical parameters and behavior in different environments. Develop and implement database and information exchange mechanisms. ($15 million)	Continue to identify and characterize unknown agents. ($25 million)
2	Biological and Chemical Agent Detectors	Adapt current slate of detectors for applications to the water-supply system. ($30 million)	Improve sensitivity of current detectors, enhance capability for real-time measurements, and extend detector capabilities to other agents. ($45 million)	Develop new generation of detectors to meet more stringent requirements associated with additional, newer agents. ($55 million)
3	Supervisory Control and Data Acquisition (SCADA) Systems	Develop vulnerability assessment criteria and techniques for SCADA systems. ($15 million)	Develop techniques to rectify security problems and preliminary protocols for design and operation of secure systems. Conduct pilot tests of improved systems. ($15 million)	Conduct additional pilot tests and develop a final set of design and operational protocols. ($25 million)
4	Vulnerability Assessment of Water-supply Systems	Develop criteria for evaluating vulnerability-reduction options. Characterize options. ($9 million)	Develop and pilot test evaluation methods and tools. ($12 million)	Apply lessons learned to methods and tools, enhance information base, improve methods and tools, and perform additional validations. ($16 million)
5	Center of Excellence for Risk Assessment of Water-supply Systems	Establish requirements for development and operation of center. Start up center. ($8 million)	Develop/test tools, models, and communication methods. ($9 million)	Continue research activities from earlier phases. Reevaluate the role of the center and adjust accordingly. ($11 million)
		Emergency Services		
6	Detectors and Detection Systems for Emergency Services	Identify requirements for known contaminants. Adapt robotic technologies for this use. Initiate basic research into the science of new detectors. ($30 million)	Produce detectors with first generation requirements. Continue basic and applied research into new detectors and robotics. ($45 million)	Develop/test a new slate of detectors and robotics for emergency services. ($55 million)
7	Integrated Emergency Management System	Specify system requirements and work on the development of a prototype system. ($13 million)	Develop and test the prototype. Develop and test a full, integrated system. ($15 million)	Complete research and deploy system. ($5 million)

Table E.2 (Cont.)

Research Topic No.	Research Topic Title	Near Term (Resource Estimate[a])	Achieved by ~2005 (Resource Estimate[a])	Achieved by ~2010 (Resource Estimate[a])
		Emergency Services (Cont.)		
8	Multihazard, Real-time Simulation and Modeling	Define requirements for such a system and initiate development. ($17 million)	Develop and pilot test a prototype system. Integrate lessons learned into next version of system. ($21 million)	Conduct additional pilot tests. Develop, test, and distribute a final set of models constituting the system. ($23 million)
9	Behavioral/Psychological Studies of Reactions to Incidents	Establish a baseline of required and anticipated responses. ($6 million)	Develop and conduct training courses. Develop and pilot test enhanced communication techniques. ($6 million)	Distribute study results and recommendations to emergency services organizations. ($2 million)
10	Decontamination Technologies	Identify and characterize appropriate existing technologies. Develop decision needs for evaluating and selecting decontamination options. ($55 million)	Focus on developing new decontamination technologies. Finalize evaluation and selection criteria for deciding what technologies are most appropriate for any given application. ($75 million)	Complete development and demonstration activities on the technologies examined in the previous timeframe. Initiate research on another set of technologies. ($105 million)
11	Systems Analysis of Public Health Emergency Response Systems	Conduct surveys on treatment capabilities and initiate development of analysis tools. ($13 million)	Develop and pilot test analytical models. Develop a preliminary set of alternative treatment practices and conduct emergency preparedness exercises. ($15 million)	Complete analysis tools. Develop/distribute information on alternative treatment practices and emergency preparedness practices. Conduct additional emergency preparedness exercises. ($17 million)
		Government Services		
12	Support Systems for Reconfiguring Government	Define basic requirements for such a system and develop a limited prototype. ($10 million)	Develop and pilot test more enhanced prototypes. ($12 million)	Complete development of the system. Test, validate, and deploy full-scale system. ($16 million)

[a] Resource estimates reflect qualitative, order-of-magnitude judgments. They are intended to be representative of the resources needed for the R&D topics and are based on assumptions concerning the scope, the expected level of effort, and the pace of the research. Detailed cost estimates must be prepared in concert with the development of detailed R&D plans.